[Karthik* *et al.*, 5.(5): May, 2016] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PROPERTIES OF CONCRETE WITH RED MUD AS PARTIAL REPLACEMENT OF CEMENT WITH HYDRATED LIME AND SUPERPLASTICIZER

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DOI: 10.5281/zenodo.52504

ABSTRACT

In this research an attempt has been made to produce different grades of concrete using huge industrial waste such as red mud as a partial replacement of cement with the hydrated lime. This project presents the results of investigation on production of concrete members using a combination of materials which predominantly includes red mud and lime. The present study is mainly focused on the compressive strength, split tensile strength, flexural strength and durability properties of concrete, which are the important parameters to be studied in concrete production of different proportion of raw materials for different grades of concrete. However, when used in combination with 30% red mud, cement and 5% lime the composites shows significant compressive strength of 27.3N/mm^2 and 50.05 N/mm^2 for M20 and M40 grade of concrete. Tensile strength of 2.60 N/mm^2, 4.98 N/mm^2 for M20 and M40 grade of concrete. Selected combinations of mixes were later used to produce beam of size 500 x 100 x 100mm.

These beams are tested for flexural strength of results 2.4 N/mm^2 and 3.29 N/mm^2 for M20 and M40 grade of concrete. From this study it is revealed that 30% replacement of red mud along with 5% hydrated lime is found to be optimum.

KEYWORDS: Red mud, super plasticiser, hydrated lime, tensile strength, flexural strength, compressive strength, M20 and M40 grade of concrete.

INTRODUCTION

It is evident from the present scenario that ordinary Portland cement is causing much of the environmental hazards such as,

- Increasing greenhouse gases
- Huge amount of power is consumed for the cement manufacture.

There is a need to find some alternative binding material. Any material which contains silicon and aluminum can be a source for replacement with cement.

Red mud is a by-product of the Bayer's process, which is obtained from the production of alumina from bauxite ore. Bauxite ore is washed and crushed and it is treated with hydroxide solution at high pressure and temperature. This process gives all the reusable alumina from bauxite ore into solution and the by-product is known as red mud. For every byproduct of alumina produced by this process, make some part of red mud as a waste. In all the countries, about 45 million tons of Red mud is produced yearly. Due to its hazards nature, it affects environment majorly.

Disposal of this waste was the most major problem faced by the alumina industry after the adoption of the Bayer process. The conventional method of disposal of red mud in ponds and pits has put adverse effect on environment. During rainy seasons, the waste may be carried by run off to the surface water which leads to the ground water contamination. Further disposal of huge amount of Red mud creates problem to the disposal site.

OBJECTIVES OF THE STUDY

- To determine the process for production of red mud concrete for different grades.
- To show the advantage of strength gained by red mud usage along with hydrated lime.
- To extend and to know the strength properties of red mud concrete in terms of compression, tensile and flexural parameters.

METHODOLOGY

- The materials are to be collected and the properties of material are to be studied as per standards mentioned in IS codes.
- Investigate the chemical composition of the red mud, lime and also its characteristic behaviour when it is replaced with cement.
- Using these properties, mix design is to be carried out with suitable w/c ratio for M20 and M40 grade of concrete.
- Required slump can be obtained experimentally by slump cone test and compaction factor test for Red mud and lime replacement with cement in percentages
- Production of concrete cubes for both M20 & M40 grade of size 150mm x 150 mm, beams and cylinders of 150mm diameter and 300 mm length to determine the compressive, flexural and split tensile strength of respective specimens. The samples will be tested at 28 days age of different proportions of red mud with hydrated lime.
- Graphs are plotted using test results and conclusions are to be made based on test results.

MATERIALS

The materials used in the experiment
1. Ordinary Portland cement (Grade 53)
2. Red mud
3. Fine aggregate
4. Coarse aggregate
5. Water
6. Hydrated lime
7. Super plasticizer (Conplast SP430)

Cement

Ordinary Portland cement of 53 grade was used in this study. The cement was tested according to IS: 12269-1987. Different test were carried out on the cement to ensure that it confirms to the requirements of the IS: 12269-1987 specifications.

Table 1: Physical Properties of the Cement

Sl. No	Characteristics	Values
1	Standard consistency	53
2	Initial setting time	30minutes
3	Specific gravity	3.09

Red Mud

The Red mud used for the replacement of cement is brought from Hindalco Steel industry Belgaum, Obtained from manufacturing of alumina from bauxite ore by Bayer's process. The characteristics of Red mud depend on the nature of the bauxite ore used.

Table 2: Characteristics of Red Mud

Sl. no	Characteristics	Values
1	Specific gravity	2.83
2	pH	10-12.5

Fine Aggregate

Locally available sand is used as a fine aggregate.

Table 3: Properties of Fine Aggregate

Property	Value
Specific gravity	2.41
Sieve analysis	Zone II
water absorption	1.2%
Silt content	4.5%

Coarse Aggregate

The coarse aggregate used in this investigation is 20 mm down size locally available crushed stone obtained from quarries. Specifications for coarse aggregate are as per IS 383:1970. The physical properties have been determined as per IS 2386:1963.

Table 4: Properties of Coarse Aggregate

Property	Value
Specific gravity	2.69
water absorption	0.48%

Water

The water used in the mix design was potable drinking water, locally available and it's free from organic materials and suspended Solids, which might have affected the properties of the fresh and hardened concrete.

Hydrated Lime

Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime to made oxides into hydroxides. Its chemical name is $Ca(OH)_2$.

Superplasticiser Conplast SP430

Conplast SP430 is a super plasticizing admixture. Conplast SP430 is a Sulphonated naphthalene polymer based admixture and is supplied as a brown liquid instantly assorted in water. Conplast SP430 has been manufactured to give high water reductions unto 25% without loss of workability and produce high quality concrete of reduced permeability.

EXPERIMENTAL INVESTIGATIONS

Mix Design for M20 Grade

The mix design procedure adopted to obtain a M20 and M40 grade concrete is in accordance with IS 10262- 2009. The details are stipulated as below,

Table 5: MIX DESIGN- As per IS 10262:2009

A-1	**Stipulations for Proportioning**	
1	Grade Designation	M20, M40
2	Type of Cement	OPC 53 grade confirming to IS-12269-1987
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content	320 kg/ m^3
5	Maximum Water Cement Ratio	M20-0.55, M40-0.45
6	Workability	M20-75 mm (Slump), M40-100mm
7	Exposure Condition	M20-Mild, M40-Severe
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content	450 kg/ m^3

Table 6: Mix Proportion – M20

W/C ratio	**Cement**	**Fine aggregate**	**Coarse aggregate**
0.50	383	557.39 kg	1052.90 kg
	1	**1.45**	**2.75**

Table 7: Mix Proportion – M40

W/C ratio	**Cement**	**Fine aggregate**	**Coarse aggregate**	**Admixture**
0.42	353	778.67 kg	1097.24 kg	7.06
	1	**2.2**	**3.11**	0.02

Fresh Properties of Concrete : Slump Test

The vertical settlement of the fresh concrete is known as slump.

Steps involved in the slump test:

- Fresh concrete is filled into a mould of specified shape and dimensions (bottom diameter of 200mm, top diameter of 100mm and height of 300mm) and the settlement or slump is measured after removing the mould.
- Increased water cement ratio increases the slump value, different slump values have been recommended for different grades of concrete.
- The slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works.
- A concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding.
- The internal surface of mould was thoroughly cleaned.
- The mould was filled in four layers and each layer was tamped with twenty five strokes of the tamping rod of diameter 16mm.
- The mould was removed from the concrete immediately by raising it slowly and carefully in a vertical direction.
- Slump was measured (in mm) immediately by determining the difference between the height of the mould and that of the highest point of then specimen being tested.

Table 8: Slump Values For M20 Grade Without Adding Super Plasticizer

Red Mud Replacement in %	Hydrated Lime in %	Slump Value	Type of Slump
20	5	20mm	True
25	5	20.5mm	True
30	5	22.5mm	True
35	5	25mm	True
40	5	27.5mm	True

Table 9: Slump Values for M40 Grade with the Addition of Conplast SP430

Red Mud Replacement in %	Hydrated Lime in %	Slump Value	Type of Slump
20	5	18mm	True
25	5	20mm	True
30	5	20mm	True
35	5	21.8mm	True
40	5	25mm	True

Compaction Factor Test

- The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of fully compacted concrete.
- It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of fully compacted volume.
- The results of compaction factor test can be correlated to slump.

$$\text{Compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

Table 10: Compaction Factor for M20 and M40 Grade of Red Mud Concrete

Red Mud Replacement in %	Hydrated Lime in %	Compaction factor M20 grade	Compaction factor M40 grade with Conplast SP430
20	5	0.81	0.82
25	5	0.81	0.82
30	5	0.89	0.86
35	5	0.96	0.92
40	5	1.21	0.98

For all % Replacement an average compaction factor is within the range.

Hardened Properties of Concrete : Compression Test

- Compression test is carried out on specimen of the size 150mm in all dimensions.
- Concrete is poured into the moulds in three layers and each layer was tamped with twenty five strokes of the tamping rod of diameter 16mm.
- The top surface is finished using trowel and keeps it for 24 hours.
- After 24 hours concrete cubes are demoulded and the specimens are kept in water for curing.
- Cubes are tested under compression testing machine to get the compressive strength of concrete at 7days, 14days and 28 days.
- The compression strength is calculated by using the formula,

$$fc = P/A$$

Where,
fc = Cube Compressive strength in N/mm^2
P = Cube Compressive load causing failure in N
A = Cross sectional area of cube in mm^2

Split Tensile Test

- The split tensile test is carried out on the cylindrical mould of dia 150mm and length 300mm.
- The inner surface of mould is coated with oil and is placed on Plate.
- The moulds are prepared by filling concrete in five layers and each layer was tamped with twenty five strokes of the tamping rod of dia 16mm. The top surface is finished using trowel.
- After 24 hours concrete cylinders are demoulded and the specimens are kept in water for curing.
- At each desired curing period (7daysand 28days) specimens are taken out from water and dried.
- The cylinders are tested in compression testing machine, applying the load diametrically to get the split tensile strength of concrete.
- The split tensile strength corresponding to failure of the specimen is calculated using the formula

$$fst = 2P/(\pi DL)$$

Where,
f**st** = Split tensile strength of concrete in N/mm^2
P is the load at failure in N.
D is the diameter of the specimen in mm
L is the length of the specimen in mm.

Flexural Test

The flexural test is carried out on the beam moulds of size 500mmx100mmx100mm.

- Concrete is poured in two layers, after each layer was poured it was compacted using needle vibrator.
- The beams were remoulded after 24hours, and then the beams were kept for curing under water for 28 days.
- After 28 days of curing the beams were removed from the water and dried.
- Testing of beam Specimens are carried out by compression testing machine, cleaning and white washing with a thin coat of lime to facilitate the detection of cracks and the propagation of cracks.
- The position at which single point loads are to be applied and the centre of the beams were marked.
- The flexural strength corresponding to failure of the specimen is calculated using the formula.

$$F_b = PL/(bd^2)$$

Where,
F_b = flexural strength of concrete in N/mm^2
P is the load at failure in N.
b is the diameter of the specimen in mm.
d is the length of the specimen in mm.

RESULTS AND DISCUSSIONS

Compressive Strength Test Results

Table 11: Compressive Strength of M20 grade Red Mud Concrete for 28 Days

Sl. no	Percentage Replacement of Red mud	Load (P) kN	Area (A) mm^2	Compressive strength (F=P/A) N/mm^2	Average Compressive Strength N/mm^2
1	20	598	22500	26.31	26.51
		607		26.7	
		603		26.5	
2	25	610	22500	26.8	26.8
		609		26.7	
		613		26.9	
3	**30**	**619**	**22500**	**27.2**	**27.3**
		621		**27.3**	
		621		**27.3**	
4	35	581	22500	25.5	25.3
		576		25.3	
		573		25.2	
5	40	551	22500	24.2	24.3
		552		24.2	
		556		24.4	

Table 12: Compressive Strength of red mud concrete of M40 grade for 28 days

Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) mm^2	Compressive strength (F=P/A) N/mm^2	Average Compressive Strength N/mm^2
1	20	1092	22500	48.04	48.22
		1097		48.26	
		1099		48.36	
2	25	1122	22500	49.36	49.17
		1118		49.19	
		1113		48.97	
3	30	1139	22500	**50.11**	**50.05**
		1133		**49.85**	
		1141		**50.20**	
4	35	1062	22500	46.75	46
		1053		46.33	
		1056		46.46	
5	40	1010	22500	44.4	43
		1002		44	
		981		43	

From the tables, it is concluded that at 30% replacement of red mud with concrete achieved higher compressive strength. Till 30% replacement the compressive strength increases with increasing red mud content. Increase in the replacement of cement with hydrated lime leads to decreasing in its strength up to 15 to 18%.

Split Tensile Strength Test Results

Table 13: Tensile Strength of Red Mud concrete of M20 grade for 28 days

Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm²	Tensile strength (F=2P/A) N/mm²	Average Tensile Strength N/mm²
1	25%	182	141372	2.54	2.58
		189		2.64	
		184		2.57	
2	**30%**	**187**	**141372**	**2.61**	**2.60**
		188		**2.63**	
		184.2		**2.57**	
3	35%	168	141372	2.3	2.24
		163		2.2	
		160		2.24	

Table 14: Tensile Strength of Red Mud Concrete of M40 Grade For 28 Days

Sl. no	Percentage replacement of red mud	Load (P) kN	Area (A) $A = \pi DL$ mm²	Tensile strength (F=2P/A) N/mm²	Average Tensile Strength N/mm²
1	20%	293	141372	4.14	4.461
		289		4.04	
		286		4.00	
2	25%	355	141372	4.986	4.664
		352		4.944	
		290.71		4.07	
3	**30%**	**354**	**141372**	**4.958**	**4.98**
		355.1		**4.972**	
		356.57		**4.99**	
4	35%	273	141372	3.98	3.8
		262		3.706	
		270		3.78	
5	40%	261	141372	3.65	3.6
		259		3.62	
		270		3.78	

From tables the split tensile strength of M20 and M40 grade red mud concrete results are observed at 28 days. Split tensile strength is higher at the replacement of 30% for both M20 and M40 grade of red mud concrete as shown in the table and graph. After 30% replacement the split tensile strength decreases with increasing replacement of red mud with concrete as shown in tables.

ISSN: 2277-9655
Impact Factor: 3.785

Flexural Strength Test Results

Table 15: Flexural Strength of Red Mud Concrete of M20 Grade for 28 days

Sl. no	**Percentage replacement of red mud**	**Load (P) kN**	**bd^2 mm^3**	**Flexural Strength F=(PL/ bd^2) N/mm^2**	**Average Flexural Strength N/mm^2**
1	25%	20	3.375	2.96	2.92
		19		2.81	
		20.2		2.99	
2	30%	21	3.375	**3.11**	**3.29**
		23		**3.40**	
		22.8		**3.37**	

Table 16: Flexural Strength of Red Mud Concrete of M40 Grade for 28 days

Sl. no	**Percentage replacement of red mud**	**Load (P) kN**	**bd^2 mm^3**	**Flexural Strength F=(PL/ bd^2) N/mm^2**	**Average Flexural Strength N/mm^2**
1	25%	34.2	3.375	5.06	5.09
		36		5.33	
		33		4.88	
2	30%	37	3.375	5.48	5.4
		36.9		5.46	
		37.2		5.51	

From tables, the Flexural strength of M20 and M40 grade red mud concrete results are observed at 28 days. Flexural tensile strength is increasing up to the replacement of 30% for both M20 and M40 grade of red mud concrete as shown in the tables. After 30% replacement the Flexural tensile strength decreases with increasing replacement of red mud with concrete as shown in tables.

CONCLUSIONS

1. Optimum percentage replacement of red mud with cement by weight is found to be 30%, it is due to the increased pozzolonic property of cement due to addition of red mud both in case of M20 and M40 grade concrete.
2. Strength results of 30% of red mud replacement concrete shows almost same results of conventional concrete of respective M20 and M40 grade concrete.
3. Red mud usage with cement leads to improvement in binding quality by showing the same setting time as conventional cement and also improves strength parameters up to 30% replacement both for M20 and M40 grade concrete..
4. After 30% replacement of red mud, the increased quantity of red mud decreases all the strength parameters and workability of the concrete both for M20 and M40 grade concrete.
5. The addition of super plasticizer for M40 grade concrete increases workability.
6. The addition of lime is contributing to enhancement of pozzolonic property of concrete both for M20 and M40 grade concrete.
7. Use of red mud, and hydrated lime in the production of concrete is showing the same strength properties as in case of conventional concrete for both M20 and M40 grades, due to presence of Al_2O_3 and SiO_2 in red mud and argillaceous content of hydrated lime.

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